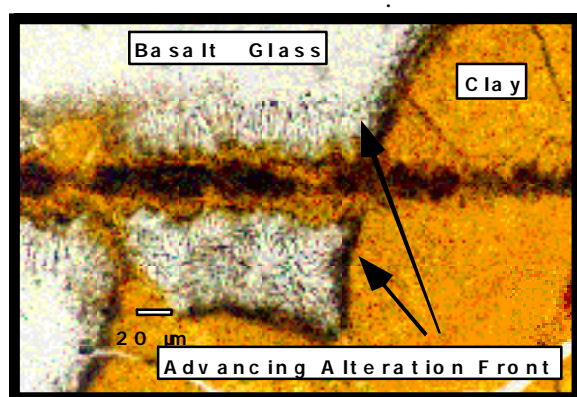


**MICROBIAL WEATHERING OF IGNEOUS ROCKS: A TOOL FOR LOCATING PAST LIFE ON**

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**Introduction:** Microbial attack of silicate minerals and glass has been observed in nature and in the laboratory, and silicate glass appears to be particularly vulnerable to attack. In igneous rocks from the oceans and on land alteration fronts progress through glass, altering it to a variety of secondary minerals. Leading the alteration front are channels and voids that are presumed to form in response to microbial activity in the rock. An example of a front is shown in Figure 1. These fronts contain carbon, phosphorus, and nucleic acids. The mechanism for the formation of the advancing channels is not known, but microbes are capable of degrading silicates with a number of extracellular organic acids and compounds.



**Figure 1:** Glass-clay microbial interface in a basalt from the Mid-Atlantic Ridge, 35°N. Clay is orange and glass is clear. Black margins between glass and clay and 1  $\mu$ m diameter channels into the glass are the zones of microbial activity. Sample depth below sea floor, 292 m. Ambient temperature, 10°C. Scale bar is 20  $\mu$ m.

**Fossils:** The channels weathered into volcanic glass come in numerous styles (Fig. 1), but all have distinctive characteristics that distinguish them from chemical weathering [1]. These channels are preserved long after microbial activity has ceased and therefore are fossil evidence of microbial activity. Organic material also remains and can be used to identify the organisms that were present.

**Subsurface Microbial Environments on Earth:**

A survey of volcanic rocks from the ocean basins has shown that microbial attack of basalt glass is a widespread phenomenon [1]. It occurs under low oxygen conditions to depths of at least 1500 m below

the sea floor, and in virtually all parts of the ocean basins where volcanic glass is present. Microbial communities have also been found in subsurface aquifers in basalts on land [2].

**Requirements for Life:** Some subsurface microbes in igneous environments appear to survive on the chemical compounds that circulate in aquifers [2]. Other requirements for life, carbon and nutrients, can be supplied by the aquifer or igneous rocks. We presume that microbes use the silicate glass as a source of nutrients, such as phosphorus or iron, and possibly as a metabolic substrate.

**Mars:** These observations of lithotrophic organisms and their associated environments on Earth are relevant to the search for life on Mars. A number of subsurface environments on Mars could support chemo-autolithotrophs [3] if there is fluid flow, at least intermittently. Sources of carbon and nutrients, as well as sources of metabolic substrates would be available as they are to the Earth's subsurface microbes. Microbial attack of silicate glass appears prevalent on Earth, so examination of Martian glass could show evidence of ancient microbial activity. Buried impact ejecta blankets would be ideal because they could act as conduits for subsurface water and they will contain glass. Impact glasses have also been found in Martian meteorites. Quenched glass exteriors of basalts would also have formed during volcanic eruptions into lakes, under icecaps, and during dike and sill intrusion into frozen ground.

**Conclusions:** (1) Microbial attack of volcanic glass produces distinctive weathering styles that can be regarded as fossil evidence of microbial life. (2) By analogy with Earth, several environments on Mars appear capable of supporting life. (3) Volcanic glass from Mars, from ejecta blankets, from shocked meteorites, or from quenched basalt exteriors could provide evidence of past life on Mars.

**References:** [1] Fisk M. R. et al. (1998) *Science*, 281, 978-980. [2] Stephens T. O. and McKinley J. P. (1995) *Science*, 270, 450-454. [3] Fisk M. R. and Giovannoni, S. J. (1999) submitted, *J. Geophys. Res.*